

**Authoring “Lab Manual 113: Microbiology for the Health Sciences”: A Quest to
Better Prepare Students for Healthcare and Save Them a Bunch of Money**

An Honors Thesis (HONR 499)

by

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Abstract

BIO 113 (Microbiology for the Health Sciences) is an introductory-level biology course with 408 seats every year and is taken primarily by pre-nursing, health education & promotion, dietetics, and respiratory therapy majors. The lab manual Dr. Bernstein and I wrote together was created to replace the previous Pearson lab manual, which was not written specifically for Ball State students. When changes needed to be made, it was challenging requesting those from the publisher. As a result the manual often included labs which were not performed at Ball State and didn't include labs that were performed. The procedures in the lab manual called for equipment not available at Ball State and often needed numerous corrections to be announced to the class before each lab session, making the use of the manual in difficult as a teaching tool. Furthermore, the lab manual was written from what appeared to be a pure microbiology perspective ignoring the primary interests of BIO 113 students. To correct this, under the guidance of and with Dr. Bernstein, I co-authored the first and second editions of "Lab Manual 113: Microbiology for the Health Sciences."

Acknowledgments

Foremost, I wish to thank Dr. Bernstein for having enough confidence in me to tackle this project with me. Throughout the writing of the manual, he has been incredibly supportive and encouraging. His advice, insight, and judgement were incredibly valuable in every step of making the first and second editions of the manual.

I wish to thank Dr. VJ Rubenstein for writing a superb Cell Biology lab manual. Your lab manual introduced and explained difficult concepts in a way that encouraged students to learn, and not simply memorize. It is this lab manual from which I judge my own.

I wish to thank Shae Baugh for her endless support and giving me feedback on the manual and my thesis. I would also like to thank you for teaching me and encouraging me to explore areas of microbiology that I otherwise would not have.

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I wish to thank Bronson Lickliter for teaching me to think analytically in biology.

Last but not least, I wish to thank my family for their endless love and support.

Process Analysis Statement

The inspiration for this project came one day during medical mycology (BOT 446) lab when the professor, Dr. Douglas Bernstein mentioned that he was planning on rewriting the BIO 113 (microbiology for the health sciences) lab manual. BIO 113 is a 5-credit hour course primarily taken by pre-nursing, dietetics, health education & promotion, and respiratory therapy students.

The project immediately intrigued me. I had taken microbiology for biology majors (BIO 313) my freshman year and had regrettably forgotten much of what was covered in the lab. I was now an outbound junior. With time removed, Ebbinghaus's curve had just sliced out what I had learned two years ago, right? I don't think so, because I had taken cell biology (BIO 215) the semester beforehand and still remembered the main takeaways from the lab. Why? Was it interest? I don't think so. I'm a microbiology major and would consider my microbial interests to be on par if not stronger than my cellular interests. Was it that cell bio lab concepts were being continually reinforced? This may partially be the case because I did research in a cellular biology lab. Yet the lab work I did investigating cellular mechanisms actually had few overlaps with the procedures in BIO 215L. Furthermore, I work in an urgent care clinic and routinely perform microbial tests and send out other samples for additional analysis.

So what made the difference? I attribute it to approach and substance. People I meet (who never seem to have much experience in the field) tell me that the discipline of biology is "just memorization." I don't think this is the case. If educators approach teaching biology by encouraging students, intentionally or not,

to memorize associations and facts, they will be quickly forgotten. If, however, students are encouraged to learn concepts to understand them and then apply those concepts to new, engaging, real-world information then students will retain information better and will be more fully prepared to critically think in the real world and apply what they know to new information. In a rapidly changing field, understanding the basic concepts of biology are far more useful than being able to recite without understanding a set of rules which are likely to become outdated at some point in a person's career. Although much of my philosophy on education might come across as armchair speculation, it is grounded in my own personal experience and the conversations I've had with fellow students.

One of the biggest problems for me was that BIO 313L didn't have a lab manual. Individual documents would be posted to blackboard before the lab. These documents contained procedures that weren't followed closely during lab and had pre-lab information that felt frustratingly sparse. I rarely understood what I was doing or the mechanisms by which reactions were occurring. It was difficult for me to orderly arrange challenging concepts spanning several labs together in my mind. To compound the problem, I didn't understand why we were doing things. I never felt like what I was doing was useful. Is this how you identify bacteria in a clinical or commercial lab? What would you do if this species was identified in various settings, what would it mean? How accurate is this test? Are there other means of determining this, which may be advantageous in certain settings? And again, how exactly is this test working?

As it turns out, most of the tests we performed in BIO 313L, as we performed them are not actually used in modern laboratories. The underlying concepts, however, do carry over and are useful. But if the concepts are not communicated clearly, then what's the point?

I don't mean to be hypercritical of BIO 313. After all, I did learn quite a lot during lecture and reading the textbook. And to be fair, a lab is only as beneficial for a student as much as they are willing to work. I took 24 credit hours, worked in a research lab about 10 hours a week, and worked at an urgent care clinic for about 20 hours per week that semester. Needless to say, it felt challenging to dedicate the appropriate amount of time for which pre-lab research and post-lab studying require. Nonetheless, I was dissatisfied with the way the lab was structured.

When Dr. Bernstein said that he was planning on writing a new BIO 113 lab manual, I felt like this might be my chance to improve the lab. Surely, I thought, BIO 113 students were experiencing something similar to what I had experienced in BIO 313.

So after hearing Dr. Bernstein's intentions, I went and talked to some nursing friends of mine who had taken BIO 113 their freshman year. They were frustrated with not being what sure what lab procedure they would be performing. In places, they felt the lab manual didn't explain the background fully or failed to communicate what exactly was happening during a lab. I politely asked if they now felt they confident in their understanding of the topics of the lab. The students I talked to said they never really did.

Needless to say, nursing students are interested in health. Although I'd estimate that very few nursing students enter their major because of an interest in microbes, microbiology plays a crucial role in the cause and complications of a large proportion of diseases. But it seems that the old BIO 113 lab manual was failing to express just how intimately connected laboratory microbiology is to health. I felt I could help Dr. Bernstein gear the language in the laboratory manual towards a more clinically-minded audience. Surely by making the manual more clinically oriented and more specific to Ball State, students would be more engaged and would consequently get more out of the lab.

I checked the Barnes and Noble Bookstore online and found that the Pearson lab manual cost \$85.70. With 408 spots open, if the courses were entirely filled and all students ordered the manual online, it would cost students up to \$34,965.60 per year.

And so, after class one day in April, I approached Dr. Bernstein with the possibility of working together on the manual. He seemed excited by the possibility. After getting a few administrative questions checked, we began planning the lab manual.

He emphasized a desire to make the lab manual "Ball State specific." We would write lab procedures with Ball State's equipment in mind and take photos of actual Ball State equipment so that when students entered the lab, they would know exactly what equipment to use and how to use it.

Dr. Bernstein was excited that by having complete ownership over the manual, it would be easier for him to make future edits. If he decided to add or nix a

lab, it would be rather straightforward for him to make the necessary corrections. If a certain step was found to be inefficient, he could change it and the next batch of students would be using the new and improved procedure.

I initially wanted to post the lab manual to Blackboard so students could download it for free or print it either in their residence halls for free or at one of the libraries for free using some their 500 free-prints students are allotted each semester. Dr. Bernstein pointed out that this might cause problems with using too many of the free-prints and might encourage students to only print off one section at a time which would inevitably lead to some students not coming with the appropriate section to lab. We decided that we could use the printing services at the Ball State Official Bookstore which could print the pages relatively inexpensively and still sell the manual at a fraction of the cost of the previous one.

We planned to write the manual in the summer. The last final of the spring semester was on May 5. I planned to take the MCAT, the entrance exam for students applying to medical school, on May 18. I hadn't studied very much for it before the end of the semester. Aware of the low percentage of students who are admitted to Indiana University School of Medicine, I decided I should dedicate my time after the semester before the exam to study.

After the exam, I took a day off and began writing the manual. I remembered the lab manuals I had used which I thought were excellent. In particular I looked at my cell biology, medical mycology, and immunology lab manuals for guidance on effective formatting.

Most of the things I wrote in the Background sections came very easily to me. I just wrote what I felt was important to understanding what they would be doing in lab and what would be relevant to their later careers in healthcare. Most of this came from textbooks I had read in other classes, what I had learned from lectures in other classes, what I had learned from other labs, what I had learned in the research labs I worked in, and perhaps most importantly from my clinical experiences and independent research I had previously done to satisfy my curiosity.

To seek out more knowledge about microbiology and how microbiology is “practiced” in clinical settings, I toured the IU Ball Memorial Hospital’s Pathology Lab and the Hoosier Microbiology Lab. I learned a lot touring both facilities and asking staff questions, but these tours reassured me that we were on the right track with the manual. The microbiological tests that the Hoosier Microbiology Lab performs, although not done on clinical specimens, were medically relevant. That being said, they are a commercial lab and can utilize equipment and tests that are cost-prohibitive for an introductory academic course. Many of the principles we introduced in this lab manual hold true for the tests that commercial labs run. If students are confronted in the future with needing to understand these commercial tests, they could hopefully rely upon the knowledge they gained in 113.

Writing the Procedures or Laboratory Exercises didn’t come quite as easily as the Backgrounds. I based steps off of Dr. Bernstein’s notes/recommendations, the Pearson lab manual, the lab manual I used in immunology (Bio 344), manufacturers’ recommendations, various online sources, and of course what I

thought would be useful. As reported by the lab Gas at the end of the semester, all of the labs “worked.”

The vast majority of microbes do not directly affect human health. Consequently, we spent very little time discussing them or incorporating them into procedures. We repeatedly worked with harmless strains of microbes either of the species of medically relevant microbes or closely related species.

Although we edited each other’s writing, I was the primary author on: Introduction to Microscopy and Microbes; Cultivation of Microbes, Microbes in the Environment and on the Skin (excluding the background), Gram Stain; Acid Fast and Endospore Staining; Morphological Unknown (excluding the background), Microbial Growth—Differential, Selective, and Enriched Media; Carbohydrate Metabolism; Control of Microbial Growth—Physical Methods; Chemical Methods of Control—Disinfectants and Antiseptics; Genus Unknown; Innate Immunity; Blood Typing; White Blood Cell Count and Identification; Rapid Antigen Detection Test for Group A Streptococcus; Universal Precautions in Action, Specimen Transport (excluding Laboratory Exercise); Dipstick Urinalysis for the Detection of Urinary Tract Infections (UTIs) (with exception of epidemiology in the Background); and Bacteria of the Gastrointestinal Tract. Of course Dr. Bernstein edited my writing much more extensively than I did his. He also contributed many of the tables and diagrams used in the lab. Usually I could only offer commas or simpler sentence structures as suggestions.

I’ve never taken BIO 113, and I’m not aware of everything that is covered in lecture. I’m also not familiar with what students come into the class knowing. It’s

often the first biology course that students take in college. A sizeable number of students, I'm guessing, never took AP Biology in high school either. Many of the students, as I learned via the feedback from the GAS, were uncomfortable doing dilution calculations. In other words, because I'm removed from the course itself, Dr. Bernstein had a much better idea of what the students know coming into the course and what they are expected to know. It was frustrating at times when he was trying to simplify the introductions I wrote because they often contained extraneous information which I felt was important, but did not directly relate to the course and may confuse students.

We created pre-lab questions that forced students to read and understand the background information in the lab and the lab procedure. The post-lab questions were designed to make students understand and explain the results they obtained and relate what their results mean in the context of the real world. I thought writing the post-lab questions was particularly fun. It made me think critically about what the "big takeaways" from the lab should be. I tried to design them in such a way to help students better appreciate why the procedure was relevant and worthwhile. In many questions, I provided additional information and asked students to incorporate the principles they had learned from the lab into the real-world information in the question. This, I think, simulates the critical thinking that professionals rely upon to problem solve and stay current in their field.

Although it was overall a fun and rewarding experience, it could be very challenging at times. This summer I started a new job as a pharmacy technician at CVS, a retail pharmacy. I continued working previously held jobs as a medical

assistant at Southway Urgent Care and as an emergency medical technician at Albany EMS. I was also applying to medical school (a task which was much more time consuming and frustrating than I had anticipated). In all of this, I was also trying to spend time with friends and my girlfriend while also still making enough time for exercise, eating, and sleep. It was admittedly a challenging summer balancing all of it.

Dr. Bernstein also had many time constraints. For example, he had to divide the time in the summer between his family, research, preparing for the next semester's classes, preparing for spring semester's classes, and writing the lab manual.

Despite our time constraints, we managed to finish the lab manual a week before classes began allowing enough time for the Bookstore to print before freshmen students arrived on campus.

After the lab manual was sent to the printers, my role for the semester was complete. I had asked students and graduate assistants leading the labs to send me feedback. I was planning on gathering all of that feedback at the end of the semester and making the necessary corrections to the manual for the next semester.

On page 3 of the original lab manual in the "Note from the authors," I asked students twice to email me if they spotted something that was unclear, a missed opportunity, or an error. Not a single student emailed me throughout the semester. At the end of the semester, I asked Dr. Bernstein to give students the following questions to gauge what they thought could be improved with the lab manual:

What labs did you think were useful and which were not? Where experimental procedures clear and easy to follow? If not, can you point out

specifically what was hard to follow? How can the lab and the lab manual be better structured? What suggestions do you have for the manual? What needs to be corrected? What was confusing about the lab manual? What was good about the lab manual? Where the pre-lab and post-lab questions a fair and accurate measure of your understanding of the lab? Are there any specific questions that you recommend taking out or adding to the lab? On a scale of 1 to 10 how important is the price of the manual? On a scale of 1-10 how important is the appearance of the manual?

After reading the responses, Dr. Bernstein offered his analysis of their feedback saying, “the lab manual needs to be bound...[needs] more pictures...[we need to] fix typos...put the Pre-Lab questions on a separate page so they could be handed in without losing info...we can make the pages more colorful by adding headers...and more help for dilution problems.”

The first lab manual was three hole punched so that students could put it in a binder and remove/return pages easily. While making the lab notebook bound would eliminate the need for buying a binder, it also prevents removed pages from being returned. Students turn in a page of pre-lab questions before each lab and a page of post-lab questions at the beginning of the next lab. These questions are then returned to the students with feedback. Presumably this feedback is a valuable learning opportunity and studying tool for students. Returning these questions to their appropriate pages in the lab manual would allow students to easily revisit these topics later on, so I don't think a bound lab manual for the second edition would be useful.

Throughout the semester, the graduate assistants leading the lab sections emailed me typos and other errors they found in the manual. For example I wrote “sport forming” instead of “spore forming” bacteria in one section. In another area, a post-lab question asked “Why might a bone marrow transplant recipient need the

same blood type as the donor?" I asked this question from an intuitive, yet outdated perspective making a false presumption. A little background first: bone marrow makes red blood cells and some white blood cells. White blood cells attack things that are "foreign." A person cannot receive a transfusion (a blood donation) from a person with a different blood type as the transfused blood will be recognized as "foreign," causing a potentially fatal immune response. My presumption was that bone marrow from someone with a different blood type would start to produce red blood cells of the donor's blood type (this is accurate) and the recipient's immune system would recognize these new blood cells as "foreign" and would therefore attack them. As it turns out, modern bone marrow donors do not have to be of the same blood type as the recipient. They do need to share a number of genetic similarities (HLA and MHC similarities), but blood type is just a small one that can be overlooked. It doesn't matter so much because the person needing the transplant usually has an immune system that has been "wiped out" by chemotherapy. As a consequence, they would have a difficult time mounting a response against the red blood cells produced by the donated bone marrow. As a result, the blood type of the recipient actually changes to that of the donor. Since this was such a complicated answer, we decided to eliminate the question. I'm glad that the GA pointed this out to me because I learned something, but we felt the answer might confuse students who were just learning the fundamentals of immunology for the first time.

We initially planned to create videos that would walk students through procedures step by step. This would certainly help students visualize how to handle equipment better and give students a better feel for certain techniques. By posting

these videos to Blackboard students would be able to watch them before coming to lab. If they still had questions after watching the videos, they could ask their lab graduate assistants. Although this would undoubtedly lead to enhanced student comprehension, Dr. Bernstein and I weren't able to find enough time to dedicate to this large task. We agreed that creating these videos in the future would be beneficial for students. Perhaps another rising honors senior will want to help make these videos this coming summer in 2018.

I really hope this lab manual improves students learning and retention, allowing them to make connections between microbiology theory and health in the real world. I learned a lot writing this manual and doing research for it. Explaining complicated scientific concepts to someone with little background in science is challenging. You need to start from the ground up, explaining each layer until you finally reach what you want to express. This is a skill I use working in healthcare, but will rely upon even more strongly when I am a physician. I'm glad that I was able to get so much experience consistently and systematically explaining microbiological concepts. I thought of a number of analogies while writing, some of which I am sure I will use later in life. For example, if I need to explain to a patient with a *Clostridium difficile* infection, a serious gastrointestinal bacterial infection, what an endospore is, I might explain in a similar way to what I wrote in the first draft of the manual.

In order to survive, bacteria need a constant supply of nutrients and environmental factors to survive. These nutrients are needed for normal cellular homeostasis. Averse environmental conditions (e.g. lack of nutrients, pH, temperature or ion concentrations) can denature (fancy term for warp) and inactivate enzymes leading to cellular death. Some bacteria possess

mechanisms to avoid this fate. They do this by forming endospores. Spore-forming bacteria sense when environmental conditions are averse, and then they begin to condense their DNA and form a protective coat around nucleoid (DNA center of bacteria). This protective coat will protect the DNA, but the rest of the cell will be excluded from the endospore and therefore sacrificed. Remember that preservation and replication of DNA is pretty much the goal of all life. So, while forming spores prevents bacteria from replicating, it allows them to protect their DNA long enough for environmental conditions improve so that they can emerge and begin to thrive again.

Endospore formation can be likened to medieval farmers flocking to the safety of a castle at the threat of a foreign army. The castle protects them from the invaders, but prevents them from tending to their fields and thriving.

Although this explanation didn't make it to the final cut of the manual and therefore won't benefit 113 students (there is another analogy in place and a less longwinded explanation that Dr. Bernstein thought of), it made me think about how I would explain it in such a way that a person with little background in the subject could understand. It made me step into the mindset of a normal person who hasn't been religiously investigating pathophysiological mechanisms for the past 8 years. Performing this exercise countless times during the writings of this manual has helped me improve my skills. Although I'm far from where I want to be in terms of converting science-speak into common English, writing this manual has helped me get closer.

I get confidence from knowing that the new lab manual is far cheaper, more clinically relevant, and Ball State specific; but I am also reassured that spending so much time in front of computer this summer was worthwhile because I know that I personally learned and am now better (if only slightly) at communicating.

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